The development of a training software to reduce the risk of wake from fast ships

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Index

Olaf Lindenau, Volker Bertram 5
The Making of a VRML Model for an SES with Streamlines and Pressure Distribution

Yvo Saanen 15
Realising Robotised Terminals: A Simulation Supported Approach

Ivan Siksne-Pedersen 29
Material Management in Shipbuilding

Zbigniew Pietrzykowski, Janusz Uriasz 40
Methods of Artificial Intelligence in Navigational Safety Assessment of Ship Encounters

Yury Nechaev, Alexander Degtyarev, Ilia Kirukhin 48
Artificial Neural Network and Genetic Algorithms in Identification Problems and Ship's Behaviour Forecast in Real Time Intelligence Systems

Edwin R. Galea, Steve Gwynne, Peter J. Lawrence, Darren Blackshields, John Ewer, Zhaozhi Wang, Nathan Hurst, Nigel Mawhinney 55
The Application of Fire and Evacuation Simulation in Ship Design

Kenneth Wauchope, Stephanie Everett, David Tate, Tucker Maney 70
Speech-Interactive Virtual Environments for Ship Familiarization

Åsmund Hellesøy 84
Escape Route Optimization through Evacuation Analysis of a Recent Ro-Pax Design

Philippe Rigo, Catalin Toderan 94
Least Cost Optimization of a Medium Capacity Gas Carrier

Jean-Yves Pradillon 108
ODIGO: A Crowd Movement Simulation Tool for Passenger Vessels

Marcus Bentin, Kunihiro Hamada, Mitsuru Kitamura 118
Multi Objective Optimization for the Master Plan of Cooperative Assembling with Several Shipyards

David Jaramillo, Tim Meyer-König 133
An XML-based Data Interface for Simulation of Passenger Evacuation

Herbert J. Koelman 140
Exploring the H-rep Ship Hull Modelling Concept

Regis Duvigneau, Michel Visonneau 154
Shape Optimization Strategies for Complex Applications in Computational Fluid Dynamics

Alessandro Giassi, Jean-Jacques Maisonneuve, Fouad Bennis 162
Multidisciplinary Design Optimisation and Robust Design Approaches Applied to the Concurrent Design

Roman Smierzchalski, Andrzej Lebkowski 175
Search Safe Ship Trajectories in Collision Situation at Sea by Evolutionary Computation

Lúcia Moreira, Carlos Guedes Soares 183
Training Recurrent Neural Networks with Noisy Data for Manoeuvring Simulation

Geert J. Tepper, Theodoor de Jonge 196
Modern Procedures in the Structural Design and Production of Ships

Dirk Steinhauer 203
The Virtual Shipyard – Simulation in Production and Logistics at Flensburger

Samuel E. Kemp, Paul A. Roach, Andrew J. Ware, Ian D. Wilson 210
Artificial Intelligence for Automatic Container Stowage Planning Optimisation

David J. Singer, Michael G. Parsons 220
Evaluation of the Effectiveness of a Fuzzy Logic Software Agent to Aid Design Team Negotiation and Communication

Desmond Simpson, Ludwig Furstenberg, Ektor Kalathas, Volker Bertram 235
Virtual Prototyping for Developing South African Ports

Bernd Klehn 247
3D-Modelling in Shipbuilding and the Missing Bricks

Stein Ove Erikstad, Arnulf Hagen 255
Web-based Tendering Collaboration in Project-Centric Industries

Antonio Rodríguez, Carlos González, Iñigo Gurrea, Lluis Solano 265
Kernel Architecture for the Development of CAD/CAM Applications in Shipbuilding Environments

Christoph Baier 278
Practical Application of Virtual Reality Technology in Engine Room Design

Trevor J.T. Whittaker, Björn Elsäßer, Christopher Cain 284
The Development of a Training Software to Reduce the Risk of Wake from Fast Ships

Martin-Christoph Wanner, Matthias Neumann, Björn Weidemann 297
Internet-Based Cooperation between Supplier and Shipyards in the Maritime Cooperation Network

Thomas Dirix, Hugo T. Grimmelius, Do (J.T.) Ligtelijn, Joost C. Moulijn 308
Generic Model Building for Concept Exploration

Thomas Hellström 321
Three Levels of Fuel Optimization at Sea

Volker Bertram 336
Cyber-Ships – Science Fiction and Reality

Kees van Es, Martin Th. van Hees 350
Application of Knowledge Management in Conceptual Naval Ship Design

Yuichi Sasaki 362
Application of Factory Simulation to the Shipyard

Larry Henesey, Fredrik Wernstedt, Paul Davidson 377
Market-Driven Control in Container Terminal Management

Virgil Mutu, Ovidiu Ionas, Ionel Gavrilescu 387
SURF – An In-House Development for a Ship Hull Design Software

Tommi Toivonen 400
NAPA System Supporting Ship Design

Robert Bronsart, Ulf Cantow, Ventzeslav Petkov 415
Linking Knowledge to Product Data

Peter Weiss, Frédéric Schom, Yves Chardard 425
Intervention of Robots in Shipbuilding and Maintenance

José Miguel Varela, Tiago Santos, Carlos Guedes Soares 432
Simulation of Fluid Dissemination in a Virtual Reality Environment Onboard the Ship

Claus Abt, Stefan Harries, Justus Heimann, Henning Winter 444
From Redesign to Optimal Hull Lines by means of Parametric Modelling

Bekir S. Türkmen, Osman Turan 459
Multi-Agent Systems In Ship Design

Kourosh Koushan 472
Artificial Neural Networks For Prediction of Ship Resistance and Wetted Surface Area

Reinhard Staebler, Matthias Grau 479
Integration of CAD and CAM Systems in Shipbuilding

Jenny Coenen, Ubald Nienhuis, Reinier Rijke, Jan van der Wagt 490
Economic Feasibility Prediction for Welding Robots in Shipbuilding

Hugo Grimmelius 502
Simulation Models in Marine Engineering: From Training to Concept Exploration

Manuel Armada, Pablo Gonzalez de Santos, Teodor Akinfiev, Roemi Fernández 516
Underwater Climbing Robot for Ship Cleaning

Stefan Krüger 525
The Role of IT in Shipbuilding

Jong Gye Shin, Kwang Kook Lee, Jong Hun Woo, Jang Hyun Lee, Se Hwan Kim 534
A Modeling and Simulation of Production Processes at a Virtual Shipyard

Wolfgang Vogel 542
IT Support for the Integrated Engineering Process of Complex Vessels

Index of authors 549

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The Development of a Training Software to Reduce the Risk of Wake from Fast Ships

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Abstract

Wash produced by fast ships can pose a significant risk to the users of the coastal region unless the routes and operational procedures are optimised. Consequently it is essential that ferry operators and their staff understand the nature of the potential risk and the measures which can be applied to reduce and even eliminate the problem. With this in mind, Stenaline Scotland commissioned the Fast Ship Wash Group at Queen's University to develop an interactive computer based training package to instruct naval officers on the nature and potential risks associated with the operation of fast ships in restricted coastal waters.

The training software, which has been developed, is divided into four sections, basic wave theory, waves produced by ships, historic problems and solutions for route optimisation and risk assessment. Wave theory and ship wash is a complex subject so the basic concepts have been explained using computer graphics to visually show the main processes. In particular the differences between the wash characteristics of slow conventional ships and high speed craft operating in shallow water are shown so that the user can understand how long period energetic waves are generated which surge and suddenly break on shorelines. The primary risks to coastal users both on land and on sea are presented and related to the wash pattern and the operation of the ship. Reduction and elimination of problems is illustrated by presenting a series of case histories of route and operational procedure optimisation using Stena Voyager, a HSS 1500 operating between Scotland and Northern Ireland, as an example. Finally an example of a risk assessment procedure is outlined which can form a significant part of the documentation needed to obtain a permit to operate in UK waters.

The rationale behind the software development is discussed with particular emphasis on how such training can improve the safety of operation of these types of ship with respect to wash. It is argued that by understanding the nature of the problem captains can avoid potentially dangerous situations particularly when they are forced to deviate from approved courses as a result of unforeseen circumstances. Consequently the training software has and will continue to make a significant contribution to the safety of users of the coastal zone when fast ships are operating in the area.

1. Introduction

During recent years the rapid growth in numbers of fast ferries has often produced problems for operators and the public close to fast ferry routes. People are at risk of being trapped against sea walls and being knocked off their feet as large waves arrived unexpectedly. Small craft are at risk from capsizing, or grounding on submerged banks, in the troughs of the very long period waves produced. Larger vessels at exposed piers can surge and break mooring lines, occasionally with damage to the dockside. The designers of fast ships may have been aware of all the effects their vessels would generate, however, the operators of such vessels often had limited understanding of the effects created when large fast vessels travel at high speed particularly near to land in shallow coastal waters. Although the application of the results of academic studies has offered solutions to some of the problems created the opportunities for improved safety from a better understanding are not necessarily available to all fast ferry operators. It should also be noted that there is no statutory requirement for this subject to be learned by operators.

2. Early Experiences Of Fast Ship Operation

The early experiences of operating a large fast ship can be illustrated by using Stena Voyager as an example. On 21st July 1996 the Stena Voyager, a HSS 1500 started service on the Stranraer to Belfast route. The vessel is 120m long, 40m beam, 4.80m draft at a displacement of around 4,000T laden and is capable of travelling at 40 knots in water depths as little as 10m. Three months earlier her sister vessel the Stena Explorer had commenced service on the Holyhead - Dun Laoghaire route and on both routes it was found that the wake effects being experienced by others at sea and around the shorelines were unacceptable. The original operational procedures closely followed the experience of the operators, gained whilst operating other smaller fast craft, as well as the limited experience gained at that time with the Stena Explorer.

The HSS's were much larger and heavier than other fast ferries operating at that time. Some time earlier, Seacat, a wave piercing 74m Incat, had started service from Belfast. Seacat's difficulties in Belfast Lough, and how they had been tackled, had been studied by the operational crew before taking delivery of the Stena Voyager. However, a full understanding of the origins of the problems was still lacking. Seacat operated a voluntary system of increasing clearance distances off problem areas thus reducing complaints. Reduction in speed was a decision resisted until it was the only option. The operators of Stena Voyager, all had previous experience of operating smaller fast craft, but had little understanding of the problems that were to be caused by a much larger vessel.

Reviewing the mistakes made at the start of service illustrates how little was understood of the creation of wash/wake effects at that time. For example, when approaching Belfast with a tanker proceeding up the dredged channel into Belfast ahead of the Stena Voyager, a reduction of speed was decided upon. On that occasion speed was reduced to 20 knots to maintain adequate clearance from the tanker. Unfortunately this produced dramatic waves on the beach at a nearby yacht club. If a specific speed had been required to make large waves then reducing to around 20knots would have been considered ideal, because it coincided with the critical values of depth Froude number and the length Froude number.

Complaints were being received along the north and south shorelines of Belfast Lough and also at P&O's Cairnryan berth in Loch Ryan. As a response to these problems, speeds close to the coast were reduced with the immediate target of preventing any further complaints and eliminating the potential risk to others. The passage times however were extended unfavourably and this was considered likely to effect the commercial success of the service. The self-imposed speed restrictions had halted the complaints but the need for a study to find reasons for the unacceptable wake was apparent. Studies were commissioned initially with SSPA of Gothenburg and then later with Queen's University Belfast. These studies showed that is was possible to produce effective operating procedures that minimised the risks associated with wake. Work was also commissioned by The Maritime and Coastguard Agency, (MCA) to study the problem and reports MCA 420, *MCA (1998),* and MCA 457, *MCA (2001),* were commissioned.

3. Requirement For Training In Wake

It was soon identified that this process was to be an ongoing development of procedures as knowledge of the subject became more and more detailed. At the same time it was noted that the masters and navigators were keen to understand the theory behind the varying approaches to resolve the wake problems. They had no previous education regarding this subject and frequently asked the same questions. These questions were mainly directed to the senior master, who was the point of contact for the studies being undertaken. Careful explanation was required and this was a time consuming process. In addition when new officers were appointed to the vessel, this process had to be repeated with each new recruit starting at the most basic level. At this time it was noted that other companies and personnel operating fast ferries for the first time were repeating the same wake mistakes which had been made earlier by the established fast ferry operators. This was felt to be arising from a high use of seasonal staff by those companies, combined with training regimes that were not fully effective

Cain (2000) was used as part of the earlier attempts to train both the Masters and Navigators of the Stena Voyager. As an educational tool this was not sufficiently comprehensive, as repeatedly the same questions were raised from those reading it.

Therefore there was a need to develop an effective training package that could explain both the basic theory, and it's application through the operational procedures developed. In addition it was thought that such a training package would help minimise the risks associated with wake, by ensuring what had been learned from the studies so far was fully understood by all. It was felt that an adequate training package would additionally be of value in fulfilling the requirements within the High Speed Craft (HSC) Code Chapter 18 'Operational Requirements'. Although wake risk prevention is not specifically mentioned within Chapter 18, provision is made for the authority to revoke the 'Permit to Operate', if safety is not maintained. This permit is only to be issued, if amongst others *"[..] crew qualifications and training, including competence to the particular type of craft and service intended, and their instructions in regard to safe operational procedures [..]"* are satisfied, *HSC (1995),* paragraph 18.1.3. and specifically 18.1.3.7). In addition it was identified that an adequate training package could assist in meeting the requirements of the MCA. The MCA requires under the HSC Code Chapter 1.9.3 that all fast craft should produce a 'risk assessment of passage plan with respect to wake. Clearly such risk assessments can be produced without the masters and navigators fully understanding the content. However, lack of understanding can lead to problems if it is necessary to deviate from the passage plan. The risk assessment passage plan is considered a "live" document by the MCA and can be the subject of review and modification in the light of complaints received. This document should be updated in the light of experiences gained and any alterations to risks identified. To produce the desired training package Stena approached the 'Fast Ship Wash' group at Queen's University Belfast.

4. Experience with Computer Based Training at Stena

The use of computer based training (CBT) had been successfully implemented for training the crew in the operation of the marine evacuation system (MES). Ability to train/educate ship's staff is not a skill that is automatically gained with rank or responsibility, and it had been seen that better results were achieved when CBT was used rather than relying on ship's officers to deliver training courses. Captains and ship's officers were seen as 'authority figures', and junior staff are often reluctant to ask for clarification of points they did not fully grasp. For this training package the target group was of widely varying educational capabilities, and consequently the CBT package was specifically designed to train those with low capabilities as well as those more gifted. Individual learning ability, determines the rate at which people progress with the fully interactive CD. This package was seen as a positive learning experience by all levels within the crew with mistakes being only seen by the computer instead of the rest of the crew.

5. Design Brief for the Wake Training Package

At the outset it was decided that the wake training package would be based on slightly different criteria to the MES training package. The wake training package is designed to form a basic educational source that could be referred back to as an authoritative reference as well as providing a positive learning experience with repeated confirmation of what had been learnt by the trainees.

The target group for the wake training package was deemed to include not only the Masters and Navigators of fast craft but also those involved in higher levels of marine operations who may have restricted knowledge of this developing subject. Many ex seafarers in higher levels of marine operations often have no experience of fast craft operations at a practical level, but they are still responsible for the implementation of safe marine operations within the International Safety Management (ISM) code.

Although the target group has a reasonably high level of education only the naval architects have studied ship hydrodynamics and basic wave theory. Consequently the main requirement was to present a highly technical and difficult subject in a way that could be understood by the non specialist. Therefore it was necessary to start from a basic level and proceed to a level of the latest international knowledge and experience of the subject. It was also considered to be essential that there should be a strong emphasis on illustrating the lessons learned from past mistakes and the solutions implemented by applying the evolving knowledge of the subject.

6. The Wake Training Package

6.1. Overview

Although there are specific computer packages for developing and presenting interactive training with highly developed graphical user interfaces, they are very specialised. This training package however was considered to be a live document as it was anticipated that the training package would need ongoing development as knowledge of the subject increased in future years. Consequently it was decided to use the commonly available package, Microsoft Powerpoint®. However, it was necessary to utilise all the more advanced features of the software in order to produce a user interface which was both attractive and obvious to use. The appearance of each screen is shown in Fig.1. This is one of the introductory screens and explains how the user navigates throughout the training package. Buttons are provided to navigate backwards and forwards from screen to screen as well as information buttons which bring up either pictures, graphics or video clips to illustrate particular points being made in the text. In addition it is possible to jump between sections using the buttons in the bottom left hand corner of the screen.

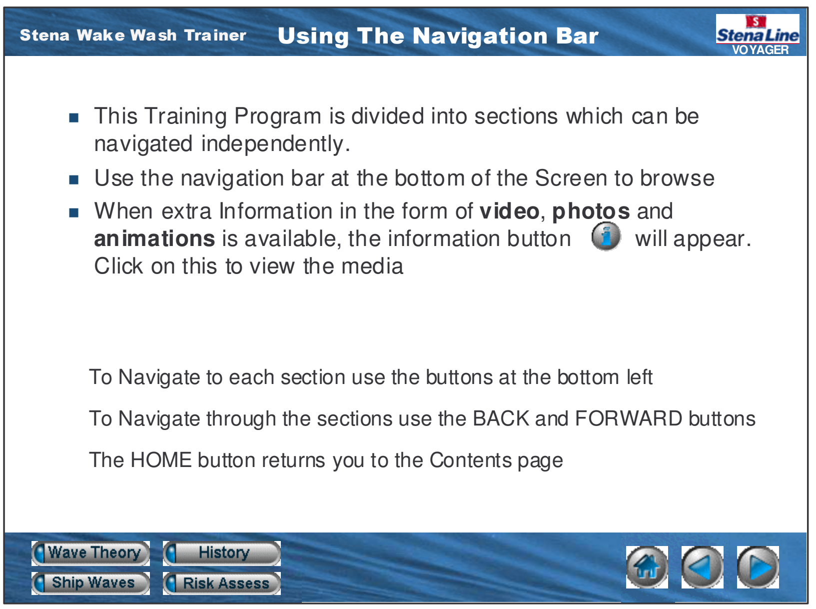

Fig.1

6.2. Contents of the training package

The training package has been divided into four main technical sections as follows, which are preceded by the introductory screens.

- Basic wave theory
- Waves produced by ships
- History – problems and solutions
- Risk management

Introductory screens
The introductory screens include a welcome page, acknowledgements and explain the use of the navigation bar, Fig.1. In addition the requirements for training, the learning objectives and the contents of the package are presented. The screen showing the requirement for training states that;

- unlike the majority of slow conventional ships, high speed ships operating in confined coastal waters produce unnatural energetic long period swell waves which arrive at the shoreline unnoticed and break unexpectedly causing risk to coastal users
- risk from wash waves produced by the increased numbers of high speed ships in recent years has raised public concern and the problem must be managed
- a basic understanding of wash waves is essential for ship operators to avoid or reduce potential risk and therefore training is essential

The knowledge the trainee should have gained by the end of the training session has been summarised as;

- the characteristics of gravity water waves
- how waves are transformed by sea bed topography
- the influence structures have on wave patterns
- the nature of wash waves created by fast ships
- how fast ship wash differs from conventional ship wash
- how vessel operation effects the wash waves produced
- how risk from wash can be avoided or reduced
- risk management procedures.

Having completed the course introduction the trainee can choose the next section to study but if a choice is not made one automatically progresses to the section on basic wave theory. Each section has a specific set of learning objectives which are clearly stated at the beginning and end.

Basic wave theory
Before trying to understand the three dimensional wave patterns produced by moving objects such as ships it is essential to study basic wave theory. This subject is often taught in coastal engineering courses at both undergraduate and postgraduate level. It is a difficult subject and would normally require 8 hours of lecturing for students to gain a basic understanding. In the training package the absolute minimum of technical material is presented and extensive use has been made of computer graphics to visualise the physical processes taking place. A description of the key variables defining a water wave is followed by details of the fluid particle motion. Computer graphics show the fluid particle motion in deep, intermediate and shallow water; the latter being the most significant for fast ship wash in coastal waters. The wave transformation processes of shoaling, refraction and diffraction are presented, again illustrated with graphics. Shoaling and refraction are the two most significant transformation processes with respect to wake.

Finally the concepts of dispersive and non dispersive waves are introduced. This is the most significant aspect as it causes the primary difference between high speed and conventional slow speed ship wash at the shoreline. In deep water waves, which are those where the wave length is greater than twice the depth, energy is dispersed from wave to wave in the group. Consequently one wave quickly becomes two and then three due to the longitudinal spread or dispersion of energy. As the number of waves increases the energy and hence height of individual waves decreases with time. However, in shallow water, where the wavelength is twenty or more times the depth, the energy in a single wave is conserved and the single wave remains without reduction of energy. The very long period leading waves in fast ship wash largely behave like this.

Waves produced by ships
This is the second and most relevant theoretical section and builds on the knowledge gained about basic wave theory. It comprises 16 main screens with a further 33 accessed by information buttons. The content is described by the opening screen and is presented in Fig.2.

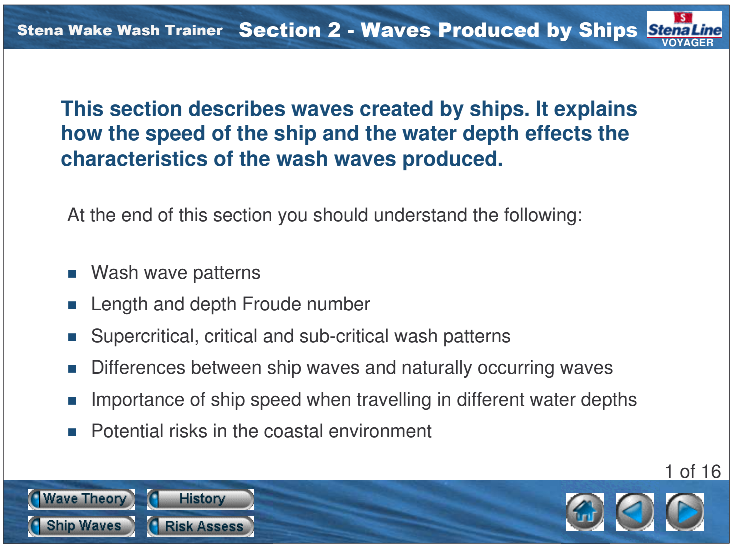

Fig.2

The section commences with a brief historic review of the work of Lord Kelvin, William Froude and others who developed the basic theory of ship wash. The 'Kelvin' wash pattern is presented and the concepts of length and depth Froude number is discussed. Naval architects normally use length Froude number, which is proportional to the ratio of ship speed and the square root of waterline length. Conversely the depth Froude number, which is primarily used to study wash waves in the coastal environment, is defined as the ratio of ship velocity and the square root of water depth. Its physical interpretation is the ratio of ship speed to the maximum velocity a wave can travel in a given depth of water. It is this wave speed / depth limitation, which determines the characteristics of high speed ship wash in shallow coastal waters.

Screen 5 and the associated information screens provides an overview of the different types of wash pattern produced in various depth Froude number ranges and illustrates the points with a series of photographs diagrams and computer animations. Fig.3 shows an example set of aerial photographs of a fast ferry operating at sub-critical, critical and super-critical depth Froude numbers.

Fig.3: Pictures of Sub-critical, Critical and supercritical wash

Unlike slow conventional ships fast ships can operate in the super-critical and critical depth Froude number ranges and it is the different characteristics of these wave patterns which causes different risk to coastal zone users. Consequently the training package concentrates on these wave patterns, produced by high speed ships, and draws the distinction between them and other wave systems such as slow speed sub-critical wash, as produced by many ships, and wind seas. In this context high speed ships have been defined as those capable of exceeding a depth Froude number of 0.85 rather than the 'High Speed Craft Code' definition.

A typical wash wave time trace measured several kilometres from the track of Stena Voyager operating within the super-critical depth Froude number range is presented, as shown in Fig.4.

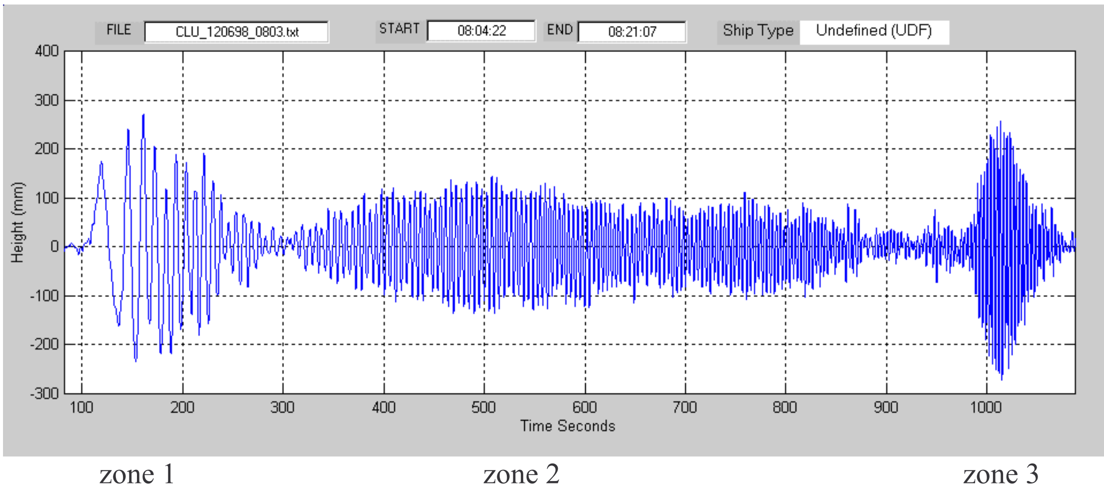

Fig.4: Super-critical wash trace showing zones 1,2 and 3

The time series is divided into zones and each is studied in detail. Additional technical information can be obtained at each stage and examples of the wake close to the ship and further away at the shoreline can be viewed. It is emphasised that it is the very long period waves in the first zone and the very short steep waves in the third zone which are peculiar to fast ships and that slow conventional ship wash is similar to zone 2. A comparison is then made between the very long period but relatively small amplitude waves in the leading part of the wash and the much higher and shorter wind induced waves produced during storms. The trainee is then reminded of the concepts of shallow water waves, non dispersive waves and shoaling, covered in the wave theory section and told that the leading waves in the super-critical wash behave like this.

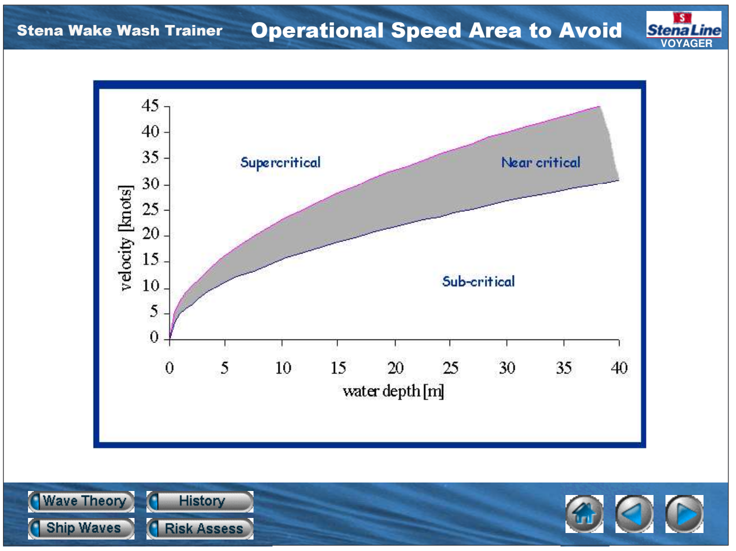

Fig.5: depth speed curve

Having covered super-critical wash attention is turned to the critical and near-critical operational zone. Here the ship speed and depth limited wave speed are the same or similar. The effect on wash pattern is analogous to an aircraft hitting the sound barrier. The photographs, graphics and output from numerical models show that the largest and most energetic waves are produced in this operational region. Consequently this region should be avoided. In practice it can not, simply because as a ship leaves port, accelerates to cruising speed and then heads for deeper water it will transcend the critical zone twice. It is explained that ships should avoid the near critical zone. A depth speed curve is presented which clearly shows the critical range of related depths and speeds, Fig.5.

However, there are circumstances when ships can become trapped in the near critical zone without sufficient power. Inadvertently generating a large near critical wash is one of the most common situations leading to wash problems. The situation where a heavily loaded fast ship possibly with the additional drag of hull fouling is entering an estuary from deep water and is down on speed is illustrated. If the ship is travelling at speed lower than the speed at which wave drag is a maximum for a given depth, resistance will rise as the water depth reduces. Thus speed will drop unless additional power is available. Consequently unless speed is reduced so that depth Froude numbers of less that 0.85 prevail, the ship can travel for a considerable distance at near critical speed dropping in speed with reducing depth and producing large transverse non dispersive waves which grow in height and spread in width. The training program instructs the trainee to recognise this situation by using the depth speed curve and to take the appropriate action.

In the final part of this section risk tables are presented in which different potential risks to coastal users in a variety of situations are related to the various zones in the wake time series. The screen shown in Fig.6 summarises the cause of the main risks posed by fast ship wash.

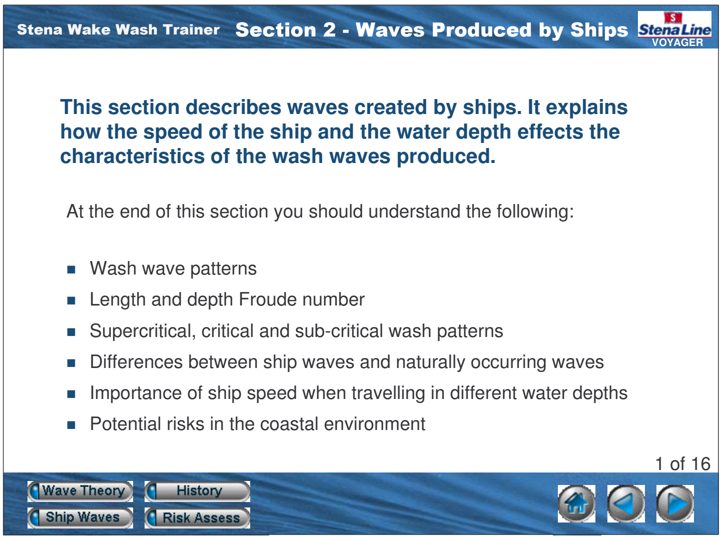

Fig.6

History – problems and solutions

The third section in the training package describes a series of case histories relating to the operation of Stena Voyager on the Belfast to Stranraer route. A range of studies have been carried out at different locations to optimise the route and operational procedure used by Stena Voyager with the aim of minimising wake problems. The work has included numerical modelling of the wash transformation processes from the ship to the shore and a substantial number of physical wake measurements at critical locations around the shoreline which bounds the route. A substantial number of the scenarios mentioned in the risk tables have been experienced during the lifetime of operation on this route. Consequently excellent training examples of what can happen, the lessons learned and the procedures implemented have application to other ships and locations. In particular the trainee can see the application of the technical aspects of the subject, which were presented in the previous sections.

Six case studies are presented highlighting different aspects of risk associated with fast ship wash and the measures adopted to manage the risk.

- *Inner half of Belfast Lough*
  This is a very shallow area with mud flats and sandbanks exposed at low tide. A dredged channel enables ships to enter the port. High speed operation results in inundation of banks and breaking waves on the shallow areas at mid to low tide causing risk to bait diggers and small boats passing over the shallows. During the top part of the tide waves surge and break on slipways and there is grave risk of people on beaches being trapped against the sea walls behind. At high tide the sea walls are overtopped in several places and coastal paths and nearby gardens flooded. In this instance the only solution has been to limit speed to 17 knots and keep well within the sub-critical range.
- *Ballyholme Bay (outer southern shore of Belfast Lough)*
  This is a horse shoe shaped bay close to the entrance of the Lough. The bed slope is very gentle and the beach is covered at high tide with water up to the sea wall in front of the promenade. The potential of trapping people against the sea wall during the top two hours of the tide and overtopping at high tide were the main risks. The problems were resolved by changing the course of the ship approaching the Lough so that the leading super-critical waves dissipated their energy on the eastern rocky headland which then sheltered the beach. As an additional precaution the ship slows at the 30m contour between one hour either side of high tide.
- *Killroot coal jetty (outer northern shore of Belfast Lough)*
  12,000T ships discharge coal to a local power station at an open jetty located on the northern shore of the outer part of the Lough. A conveyer discharges the coal from the hold into a hopper on the quay. The ship is moored with fore and aft lines, brest lines and springs plus a short midship line to prevent the ship ranging on the berth and the coal missing the hopper. The long period leading waves in the wash causes the ship to range several metres breaking the short lines which end up taking most of the strain. At present the problem has been resolved by slowing when the jetty is 70^{o} off the bow during the inbound passage and delaying acceleration on the outbound passage until after the 70^{o} bearing. An additional precaution has been the fast ship warning the moored ship of its approach. However, these procedures are only applied when the berth is occupied. Otherwise high speed operation continues to the fairway buoy and acceleration starts at buoys 3-4 on the outbound passage.
- *Beaches at Crawfordsburn and Helens Bay*
  Occasional large wash events were reported. This was identified as being caused by prolonged near critical speed operation in the outer part of the Lough for the reasons discussed in a previous section. The problem was resolved by dropping speed when the critical speed trap was encountered.
- *Loch Ryan inner part*
  This is a similar situation to the inner part of Belfast Lough except the channel is 4m shallower and narrower. An open Ro-Ro ferry terminal is located at the seaward end of the channel. Even with the fast ships travelling at sub-critical speeds the link spans at the terminal were excited by the short period but steep waves in the Kelvin wash. This could only be resolved by very low speed operation of 12 knots.
- *Loch Ryan (outer part)*
  This case study demonstrates the use of speed steps, wave focusing on the inside of turns and seasonal variations in ship operation to accommodate nesting of 'Little Terns' on low lying pebble banks. In Loch Ryan there is a deeper trench to seaward of Cairn Point. This can be used in the deceleration phase to transcend the critical zone very rapidly by dropping speed simultaneously with a sudden increase in depth. Wave focusing inside the turn into the loch is shown which can cause problems in some areas. However, in Loch Ryan the wave is concentrated on a remote rocky headland. During May early June a colony of Little Terns nest on a bank which is normally over-washed at high tide by the leading waves in the super-critical wash travelling down the loch. Early slow down on the few sailing effected avoids the problem and shows how pragmatic speed restrictions at certain times can avoid a blanket speed restriction.

The most important outcome from this section is that it shows what can be done to manage the consequences of fast ship wash. Also it clearly demonstrates that single measures do not resolve the problems in all cases. Consequently it is emphasised that each part of every high speed ship route close to land must be assessed individually and the most appropriate operational procedure adopted. Often it is possible to vary the procedure to account for tide level, the proximity of other ships and even the nesting times of wildlife.

Risk management

In the final section the trainee is presented with a list of measures which can be adopted to manage the potential risk from high speed ship wash as well as the methods of risk assessment and the production of passage plans. At present there is not a statutory standard for preparing the documentation required for the route assessment with respect to wake wash as part of the paperwork required for the permit to operate which must be obtained from the MCA. The screen shown in Fg.7 explains the current position.

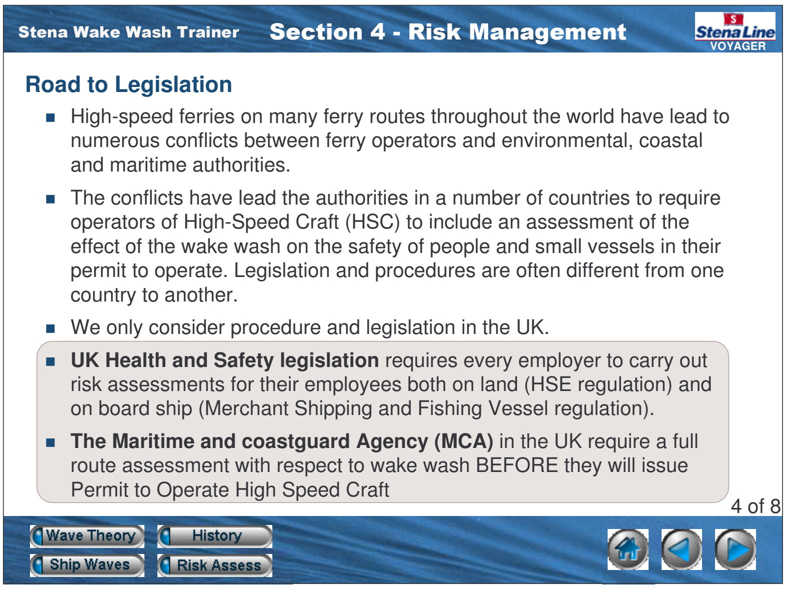

Fig.7: Road to Legislation

In some countries in the world simple formulae are applied to determine the maximum height of wash wave that is permitted at a certain water depth off the shoreline. Unfortunately this tends to be over simplistic and it can be argued that it does not necessarily prevent risk in many cases. In the UK the risk assessment document is live and incidents or complaints about wake are logged. The offenders are required to reconsider their route assessment document and if deemed necessary alter their operational procedure. Consequently the trainee is left with the clear picture that if he or she is operating a fast ship it is their responsibility to ensure that the potential for wake incidents is minimised particularly when the ship is forced to deviate from the specified operational procedure due to unplanned circumstances. This can be as simple as avoiding other shipping on the planned route and for example the consequences of course changes and the resulting wave focusing on the inside of turns needs to be understood. A further example is the potential consequences of passing other vessels both large and small when accelerating though the critical speed range particularly in channels and estuaries of confined width. The possibility of grounding of large vessels constrained by their draft is a further example.

7. Consumer Feedback

An important consideration when producing an effective computer based training package is to seek a critical review of the work produced before the final version is implemented. Ideally the training package should be presented to a selection of the target group it is intended for, with constructive feedback being encouraged. As had been learned with the production of the MES training CD, this was a fundamental step in the process to achieve a successful training package for wake.

During this process the first draft of the CD was distributed throughout Stena Line in the areas where feedback was considered as being assured. Stena Line's own naval architects in Sweden were sent a copy of the 1st draft as well as senior managers involved with the safety management of Stena Line both in Sweden and the UK. By including these groups it was hoped that the review would have input from as wide a group as possible. Some of these naval architects were involved with the design of the HSS craft, and therefore had detailed knowledge of the craft. The CD was also made freely available to the masters and navigators of the Stena Voyager and critical review requested from all. Adequate time for reviewers to consider the training package was essential. The review criterion for others not involved in the making of the CD was to consider the total concept and the delivery of the training. This process took a little longer than expected but the comments received have been of considerable value and were considered carefully by the development team at Queen's.

This feedback process was a success and very little was identified as requiring change. The main addition suggested was the inclusion of more video clips of actual wash action. A consistent comment received during this feedback process from all areas was, "[..] this CD should be distributed to all the HSS 1500's".

Feedback from the naval architects made very little reference to the basic theory section however they did regard the explanation of how theory could be used to provide the answers to problems as very good. The naval architects were not being shown anything within the theory section that they did not have full knowledge of, however, attempting to teach this theory to either reduce or eliminate problems created, was new to them.

These comments were very positive as they indicated that the target group of masters and navigators as well as the most senior management of the company valued the work achieved so far, and felt it should be shared throughout the company. Consequently after the inclusion of the suggested additions, copies of the CD were sent to both the Stena Explorer and the Stena Discovery. This training package now forming the company standard for all HSS 1500 vessels with respect to wake issues.

8. Potential for Improved Safety as a Result of Training

Reduced risk from passage plan deviations

The package, by raising the understanding of both theory and the solutions to potential problems, provides the best option to help to prevent future incidents where coastal users are placed at risk. As previously discussed, this is particularly important when deviation from the passage plan is forced upon the vessel. Wake problems have occurred due to altering course to avoid other vessels resulting in deviation from the specified course line. Also, unplanned reductions in speed to a critical value have caused problems. After training the masters involved with these incidents readily accept that they have the capability to reduce the risk to others from wake in these situations now that they understand the consequences of the different actions they can take.

Reduction in environmental impact

Knowledge enables the operators of fast ships to act in a responsible manner with respect to the environment. The potential risk from wake to a very important breeding area for terns in Loch Ryan during their breeding season is a notable example. This breeding colony contains different varieties of terns including some rare species. Working with the RSPB and applying the knowledge of wake propagation to the situation, an early reduction in speed at times of higher tides resulted in removing the risks to the terns. There was a small impact on crossing times for the Stena Voyager but this was more than offset by the very positive thanks received from the local RSPB representative. Instead of being viewed as commercial company operating purely for profit the company was seen as being a safe operator who was prepared to make efforts to operate with due regard for environmental issues.

The wider application of training

There is a need to produce a similar training package for all operators and crews of fast ships as a method of raising awareness throughout the marine industry. This could be extended to the provision of informative material to yacht clubs, boat clubs, sea based leisure organisations and schools.

A recent incident involving a smaller fast ship near Cowes resulted in the Marine Accident Investigation Branch, (MAIB), investigating the causes of this incident. The final report on this incident has not yet been published, however, during their investigations the MAIB became aware that Stena Line had produced their own training CD and requested a copy. This was provided on a 'commercial in confidence' basis to them and during a visit to them the reasoning behind the production and format of the training software was explained. The MAIB were interested to know how problems had been identified and addressed to improve safe operating procedures.

Incidents involving wake are mainly preventable by a full understanding of the problems involved, It seems likely that this subject will soon have to be studied by all operators, masters and navigators of vessels capable of creating wake problems. It is not however correct to wait for possible legislation changes to identify and provide a solution to the lack of education for those involved on a day to day basis.

Measures of success
As procedures have been developed in the light of the results of the various studies completed there followed a drop in Insurance claims from wake issues. Commercial companies are largely driven by an improvement to the balance sheet as well as safety factors. To illustrate the benefits of close co-operation between the operators and the academics and the development of training, ***figure 8*** shows the wake Insurance Claims made against the claims paid for during the first three years in service of the Stena Voyager. It should be noted that the claims made also include the claims that have not been honoured due to being false.

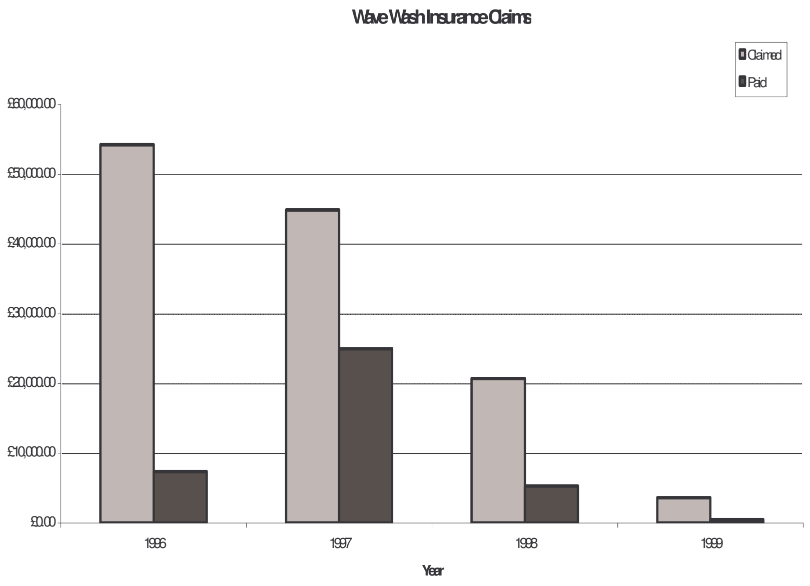

Fig.8: Insurance claims with respect to wake from Stena Voyager

Much can be achieved by ensuring that the public, are aware of the dangers from the wash of high speed ships. Warning signs are of most benefit to visitors to the area, since the local population are usually experienced with the effects from other ferries and adjust to the new risks. However those involved in marine operations at a high level should be able to understand why and how improvements to reduce risk can be achieved.

The illustration regarding insurance claims reinforces the success of applying the lessons learnt from theory to operational procedures. Increased safety through improved operational procedures can also be seen to have a positive financial impact. Safety is often thought as a cost alone but by proactive management insurance liabilities can be minimised and costs reduced for both operators and insurers.

9. Concluding Remarks

A computer based training package has been produced on the various aspects of wake produced by fast ships. This is in response to public concern regarding the additional risk resulting from the characteristics of the waves produced. The development of a computer based training system has significantly reduced risk to others and has the potential for wider application. It has already been adopted by all the HSS 1500's operating in Stena Line. Training and information transfer has been shown to have a direct impact on the number of wake related incidents and the resulting insurance claims.

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